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ORIGINAL ARTICLE

Functional limitations and poor physical performance as independent risk factors for self-reported fractures in older persons

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Abstract Objective: This study examined whether three aspects of functioning (i.e., functional limitations, physical performance, and physical activity) were associated with fractures in older men and women. Design: A 3-year prospective cohort study. Participants and setting: A total of 715 men and 762 women, aged 65 years and older, of the population-based Longitudinal Aging Study Amsterdam. Measurements: During an interview at home, three aspects of functioning were assessed: functional limitations (what people say they can do), physical performance, i.e., three performance tests and handgrip strength (what people are able to do), and physical activity (what people actually do). Afterward, a follow-up on fractures was conducted for 3 years. Results: 77 patients (5.2%) suffered a fracture during 3-year follow-up. Most patients suffered a hip fracture (1.6%) or a wrist fracture (1.4%). The fracture rate per 1,000 person-years was 20.1. During 3-year follow-up, a fracture was reported by 12%, 10%, 12%, and 6% of the respondents with functional limitations, low performance test score, poor handgrip strength, and low physical activity, respectively. Using Cox proportional hazard analysis, functional limitations (RR = 3.5; 95%CI, 2.1 to 6.0), low performance test score (RR = 1.9; 95% CI, 1.1 to 3.3), low handgrip strength (RR = 2.5; 95% CI, 1.5 to 4.1), and low physical activity (RR = 1.9; 95% CI, 1.1 to 3.5) were significantly associated with fractures after adjustment for age and sex. Functional limitations (RR = 3.2; 95% CI, 1.8 to 5.5), low performance test score (RR = 1.8; 95% CI, 1.0 to 3.3) and low handgrip strength (RR = 2.0; 95% CI, 1.1 to 3.6) remained significantly associated with fractures after additional adjustment for body composition, chronic diseases, psychosocial factors, life style factors, and the other levels of functioning. No significant interaction terms were found. Conclusions: Functional limitations and poor physical performance were independent risk factors for fractures.

Keywords Aged · Cohort study · Disability · Fractures · Physical activity · Risk factors

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Introduction

The incidence of fractures increases with age [1]. About 40% of women and 13% of men will experience at least one fracture during their remaining lifetime, based on average life expectancy [1]. The older population is increasing worldwide, which means that the total number of fractures will increase. Fractures are a frequent and important cause of disability [2]. Furthermore, the risk of death is elevated in persons who suffer a hip or vertebral fracture [3]. Because of these severe consequences and the related high medical costs, prevention of fractures is important.

Although prophylaxis with several drugs, such as bisphosphonates, can reduce the number of fractures [4], the risk reduction can be improved by introducing other intervention strategies. Studying treatable risk factors in a prospective cohort study might help to determine which risk factors should be included in an intervention strategy. Only a few prospective cohort studies have examined the association between treatable risk factors, such as physical functioning, and the risk of hip fractures [5, 6, 7] or other osteoporotic fractures [8, 9, 10].

Glass and colleagues made a distinction between three aspects of physical functioning: hypothetical (questions about functioning), experimental (physical performance), and enacted functioning (physical activity) [11]. The association between the three aspects of functioning and the occurrence of fractures has not been investigated. Moreover, Glass et al. showed that discordance could exist between what people say they can do, what they are able to do in standard physical performance tests, and what they actually do [11]. Glass and colleagues suggested that older persons who are functioning at a higher level than suggested by their ability are "overachievers." These persons might have a higher fracture risk. It is also probable that inactive persons with functional limitations and poor physical performance have a higher fracture risk.

The objective of this prospective study was to examine whether three aspects of functioning (i.e., functional limitations, physical performance, and physical activity) were associated with fractures in older men and women.

Methods

Sample

This study on fractures was performed within the Longitudinal Aging Study Amsterdam (LASA). LASA is a population-based study, mainly consisting of community-dwelling older persons. A random sample of 3,805 older men and women (aged 55–85 years) stratified by age, sex, and expected 5-year mortality, was drawn from the population in The Netherlands [12]. At baseline (1992/1993), 3,107 respondents of the 3,805 persons (81.7%) were willing to participate. Every 3 years a LASA examination was performed, consisting of a main and medical interview. The sampling and data collection procedures have been described in more detail elsewhere [12].

After the medical interview of the second examination (1995/1996), a follow-up on fractures (and falls) was conducted for 3 years. Only those respondents who were 65 years or older as of 1 January 1996 were eligible for the fracture follow-up, because fractures mainly occur after the age of 65 years [1]. Of the 2,302 respondents who completed the second main interview, 1,720 respondents were 65 years or older. Of these, 211 respondents did not complete the second medical interview, because 160 respondents refused, 43 were not capable, 5 died before they were approached, and 3 could not be contacted. Therefore, 1,509 respondents were eligible for the fracture follow-up. Of these, 1,451 respondents started the fracture follow-up. Of the 58 respondents who did not start the fracture follow-up, 26 respondents completed the third data-collection cycle (1998/1999) including retrospective data collection on fractures. These data were added to the data from the prospective fracture follow-up. The other 32 respondents who did not start the fracture follow-up, either refused ($n=26$) or were not capable of starting the follow-up ($n=6$). This means that data on fractures were obtained in 1,477 respondents. Informed consent was obtained from all respondents, and the study was approved by the Ethical Review Board of the VU University Medical Center.

Fractures

After the second LASA data collection (1995/1996), data on fractures were prospectively collected using a calendar for a period of 3 years. Respondents were asked to report their fractures every 3 months on a calendar and to mail the calendar page to the institute at the end of this period. Respondents were contacted by telephone if they were unable to complete the calendar, if the calendar was not returned even after a reminder, or if it was completed incorrectly. Furthermore, during the third data collection (1998/1999) information about fractures was collected retrospectively.

The general practitioners of the respondents were asked to confirm the reported fractures. In addition, when a participant died, the general practitioner was asked whether a fracture had occurred since the last contact with the participant. In case of doubt, radiographs were obtained from the hospital and checked by a clinician. A fracture was classified as a "definite fracture" (i.e., the self-reported fracture was confirmed by the general practitioner or clinician) or as a "possible fracture" (i.e., the general practitioner and clinician could not give any information). Fractures of the toes, fingers, and head were excluded, as well as fractures caused by a motor vehicle accident.

Physical functioning

Trained research nurses visited the respondents at home during the second LASA data collection (1995/1996) and three aspects of functioning (i.e., functional limitations, physical performance tests, physical activity) and the potential confounders were assessed.

Functional limitations were assessed with a validated questionnaire concerning the degree of difficulty with the following activities of daily living: climbing stairs, walking 5 min outdoors without resting, getting up and sitting down in a chair, dressing and undressing oneself, using own or public transportation, and cutting one's own toenails [13]. The scores on these six items were summed to a total score that ranged from 0 (does not have any difficulties with the activities) to 6 (has difficulties with all activities).

Physical performance included performance tests and handgrip strength. The performance tests included a timed walking test, chair stand test, and tandem stand [14]. To test walking performance, a 3-m walking course was created with a measuring line. Participants were instructed to walk to the other end of the course, to turn 180°, and to return as quickly as possible. They were allowed to use a walking aid if needed. To test the ability to rise from a chair, persons were asked to fold their arms across their chest and to stand up and sit down five times from a standard kitchen chair as quickly as possible. The total time to complete each of the two tests was recorded by a trained research interviewer, and a standard protocol was used throughout the study. The tandem stand was the ability to stand with one foot placed behind the other in a straight line for at least 10 s. Those completing the walking test and chair stands were assigned scores of 1 to 4, corresponding to the quartiles of time needed to complete the test, with the fastest time scored as 4. Those who could not complete the test (e.g., because they were physically not capable) were assigned a score of 0. For the tandem stand, 0 points were given to those who could not perform the tandem stand, 2 points to those who stood less than 10 s, and 4 points to those who stood at least 10 s. The three items were summed to a final score (range 0–12) [14]. Handgrip strength was measured with a strain-gauged dynamometer (Takei TKK 5001; Takei Scientific Instruments, Tokyo, Japan). Respondents were asked to perform two maximum force trials with each hand. For the final score the highest values of the right and left hand were summed, and divided by two [15].

Physical activity was assessed with the validated LASA Physical Activity Questionnaire (LAPAQ) [16]. The LAPAQ is a face-to-face questionnaire that covers the frequency and duration of walking outside, bicycling, gardening, light household activities, heavy household activities, and a maximum of two types of sport activities during the previous 2 weeks [16]. Walking and bicycling for transportation purposes are considered as common daily activities in The Netherlands, and not as sport activities. The participants were asked whether the activity pattern of the previous 2 weeks was representative of the rest of the year. For the analyses, the total time spent on physical activity of the last 2 weeks was used (in minutes per day). This can be calculated by multiplying the frequency and duration of the individual activities in the previous 2 weeks, summing these values across activities, and dividing by 14. Moreover, an intensity-weighted total physical activity score was calculated by multiplying the total time with the MET score (i.e., 1 MET unit corresponds to the resting energy expenditure that corresponds to 1 kcal per kg body weight per hour) of each activity in the previous 2 weeks, and summing these values across activities [16].

Potential confounders

Several variables might be associated with physical functioning and fractures and were therefore considered as potential confounders—including age; sex; body mass index; number of chronic diseases including chronic obstructive pulmonary disease, cardiovascular disease, stroke, diabetes mellitus, malignant neoplasms, and joint disorders [17]; medication use; regularly dizziness (yes/no); fracture in past 3 years (1992–1995) (retrospectively asked); cognitive impairment (Mini-Mental State Examination) [18]; depression (Center of Epidemiologic Studies Depression Scale) [19]; current smoking (yes/no); and alcohol use (number of glasses per week). Furthermore, the associations were adjusted for the other aspects of functioning (e.g., functional limitations and physical performance) if the potential confounder and the risk factor at issue (e.g., physical activity) were not strongly correlated (Spearman correlation <0.60) and if the potential confounder could not be considered as an intermediate variable.

Statistical analysis

To check for attrition, we compared the participants ($n=1{,}477$) with the nonparticipants ($n=32$) on all variables that were included as potential risk factors or confounders, using the χ-square for dichotomized variables, *t*-test for continuous variables, and a Mann-Whitney test for skewed continuous variables ($p<0.05$). Similar tests were used for comparing baseline characteristics between respondents with and without a fracture.

For illustrative purposes, results were presented using dichotomized risk factors (i.e., functional limitations, performance tests, handgrip strength, and physical activity). Additionally, we checked whether similar results were obtained using continuous risk factors. For the dichotomized risk factors, the risk gradients across deciles and quartiles were examined, and the optimal cutoff point was chosen—i.e., the quartile or decile that showed the strongest association with fractures. Because handgrip strength is generally higher in men than in women, sex-specific cutoff points were taken. The cut-off point for the potential confounders depression (CES-D $\geq$16) and impaired cognition (MMSE ≤ 24) were chosen at pre-established points [18, 19].

For all analyses described below, respondents with missing values on each of the risk factors at issue were excluded. Kaplan-Meier curves were used to examine the unadjusted associations between the risk factors and time to the first fracture. With the log-rank statistic we compared whether the Kaplan-Meier survival curves were significantly different. The unadjusted and adjusted associations between the risk factors and the time to the first fracture were studied using Cox proportional hazard regression analysis. After adjustment for age and sex, additional adjustment was only performed for those confounders that changed the association (β) by at least 10%. We graphically assessed the assumption of proportionality for each of the confounders. If there was an indication for nonproportionality, interactions between the confounder and time to fracture were considered as well.

Age and gender were tested to see if they were significant effect modifiers ($p<0.10$) in the associations between risk factors and fractures. To examine whether overactive persons with functional limitations or a low physical performance had a higher risk of fractures, we tested whether physical activity was an effect modifier ($p<0.10$) in the association between functional limitations, physical performance, and fractures. Furthermore, functional limitations or physical performance were tested to see if they were significant effect modifiers ($p<0.10$), because inactive persons with functional limitations or poor physical performance might have a higher fracture risk. Additionally, persons with both functional limitations and poor physical performance might also have a higher fracture risk.

Censored data concerned those in whom the 3-year fracture follow-up was discontinued because they died, refused to continue, or were not able to continue the follow-up.

Relative risks were calculated with 95% confidence intervals. For all analyses, the Statistical Package for the Social Sciences (SPSS for Windows, version 9.0) was used.

Results

Sample

The sample included 715 (48.4%) men and 762 (51.6%) women. The mean age was 75.8 $\pm$ 6.6 years (range 64.8–88.8). Nonparticipants ($n=32$; 2.1%) were older, had more functional limitations, had a lower score on performance tests, had a lower handgrip strength, and were more cognitively impaired than the participants ($n=1{,}477$) of the study ($p<0.05$).

The number of missing respondents for each risk factor was 24 for functional limitations (1.6%), 83 for performance tests (5.6%), 42 for handgrip strength (2.8%), and 137 for physical activity (9.3%). Furthermore, the number of functional limitations (men 1.2 $\pm$ 1.6 points; women 1.9 $\pm$ 1.8 points), the score on the performance tests (men 8.1 $\pm$ 3.1 points; women 6.9 $\pm$ 3.5 points), and handgrip strength (men 33.8 $\pm$ 8.5 kgf; women 19.6 $\pm$ 5.4 kgf) did significantly differ between men and women ($p<0.05$). No significant difference was found for physical activity between men (137 $\pm$ 106 min) and women (173 $\pm$ 102 min) ($p=0.40$).

Three-year fracture follow-up

Of the 1,451 respondents who participated in the prospective fracture follow-up, a majority (83.4%) completed all 12 periods of 3 months of follow-up. In the 1st year of follow-up, 27 respondents suffered their first fracture, while in the 2nd year 25 and in the 3rd year 25 respondents had their first fracture. Sixty-six fractures (85.7%) were reported prospectively on the fracture calendar (1995/1996 through 1998/1999), whereas 11 more fractures (14.3%) were reported at the third data collection cycle (1998/1999). Seventy fractures (90.9%) were defined as "definite" and seven fractures (9.1%) were defined as "possible" fractures. Possible fractures were fractures from the wrist ($n=1$), rib ($n=2$), ankle ($n=2$), and other lower extremities ($n=2$). Table 1 shows the types and numbers of the first fracture of the 77 patients (5.2%) who sustained a fracture during the 3-year follow-up. Most respondents suffered a hip fracture (1.6%; $n=10$ women and $n=14$ men) or wrist

Table 1 Types and numbers of the first fracture sustained during 3-year follow-up in women and men ($n = 1{,}477$). Fractures of the toes, fingers, and head were excluded, as well as fractures caused by a motor vehicle accident

Type of fracture	Women ($n = 762$)	Men ($n = 715$)
Hip	10	14
Other lower extremity[a]	8	4
Wrist	15	6
Humerus	6	3
Other upper extremity[b]	1	0
Other[c]	7	3
Total	47	30

[a]Femur, tibia, and ankle fractures
[b]Clavicle fractures
[c]Pelvic, rib, and vertebral fractures

fracture (1.4%; $n = 15$ women and $n = 6$ men). Four respondents reported a vertebral fracture ($n = 3$ women and $n = 1$ men). Two uncertain hip fractures and two vertebral fractures were confirmed by a radiograph by a clinician. Table 2 shows the baseline characteristics of respondents with ($n = 77$) and without ($n = 1{,}400$) a fracture during the 3-year follow-up.

The difference in cumulative fracture free survival between men ($n = 30$) and women ($n = 47$) was not significant (log-rank statistic $p = 0.23$). Age was not significantly different between men (79.1 ± 6.3 years) and women (77.5 ± 6.9 years) who suffered a fracture ($p = 0.324$).

Association between functioning and fractures

The total fracture rate per 1,000 person-years was 19.7 (standard error = 3.7) at 1-year follow-up and 20.1 (standard error = 2.3) at 3-year follow-up (Table 3). The fracture rates per 1,000 person-years after 3-year follow-up for each dichotomized risk factor, i.e., functional limitations, performance tests, handgrip strength, physical activity, are also shown in Table 3. Figure 1a–d shows the Kaplan-Meier survival curves of the associations between the risk factors and fractures. The Kaplan-Meier survival curves were significantly different (log-rank statistic $p < 0.05$). During 3-year follow-up, a fracture was reported by 12%, 10%, 12%, and 6% of the respondents with functional limitations, low performance test score, poor handgrip strength, and low physical activity, respectively (Fig. 1a–d).

Using Cox proportional hazard regression, the associations between all risk factors and fractures were statistically significant, unadjusted and after adjustment for age and sex ($p < 0.05$) (Table 4). Additional adjustment for body mass index, number of chronic diseases, medication use, dizziness, fracture in the preceding 3 years (1992–1995), cognitive impairment, depression, current smoking, and alcohol use did not change the associations by at least 10%, and therefore no additional adjustment for these confounders was performed. After additional adjustment for other aspects of functioning, functional limitations, a low performance test score, and

Table 2 Baseline characteristics of respondents with and without fractures. Results are presented as mean ± standard deviation, median (25–75 percentile), or percentages

	Fractures ($n = 77$)	No fractures ($n = 1{,}400$)	p Value
Age, years	78.2 ± 6.7	75.7 ± 6.6	< 0.05
Sex (women), %	61.0	51.1	0.09
Functional limitations (range 0–6)	3 (1–4)	1 (0–2)	< 0.001
Performance tests (range 0–12)	6 (3–9)	8 (6–10)	< 0.001
Handgrip strength, kgf	21.3 ± 8.4	28.6 ± 10.0	< 0.001
Physical activity (LAPAQ), min/day[a]	112 (56–173)	141 (79–212)	< 0.05
Body mass index, kg/m^2	26.6 (4.3)	26.9 (4.3)	0.48
Number of chronic diseases (range 0–7)	1 (0–2)	1 (0–2)	0.38
Number of medications	3 (1–5)	2 (1–4)	0.63
Dizziness, %	22.1	15.1	< 0.05
Fracture in past 3 years, %	6.5%	5.5%	0.71
Cognitive impairment, % (MMSE score ≤ 24)[b]	34.2	19.7	< 0.001
Depression, % (CES-D ≥16)[c]	27.8	18.0	0.15
Current smoker, % (yes)	20.8	18.9	0.68
Alcohol use, number of glasses per week	1 (0–7)	3 (0–8)	< 0.05

[a] *LAPAQ* LASA Physical Activity Questionnaire,
[b]*MMSE* Mini-Mental State Examination,
[c] *CES-D* Center for Epidemiologic Studies Depression Scale

Table 3 Association between functional limitations, performance tests, grip strength, physical activity, and fractures after 3-year follow-up

	Number of respondents	Number of Fractures	Person-years	Fracture rate[a]	Standard error fracture rate
Total sample	1,477	77	3,827	20.1	2.3
Functional limitations (< 2)	898	23	2,458	9.4	2.0
Functional limitations (≥2)	555	53	1,353	39.2	5.4
Performance tests (score > 6)	920	30	2,509	12.0	2.2
Performance tests (score ≤ 6)	474	36	1,188	30.3	5.1
Handgrip strength (high)[b]	1,164	45	3,113	14.6	2.2
Handgrip strength (low)[b]	271	28	651	43.0	8.1
Physical activity (> 180 min/day)	535	15	1,459	10.3	2.7
Physical activity (≤ 180 min/day)	805	45	2,097	21.5	3.2

[a]Fracture rate per 1,000 person-years
[b]High handgrip strength: men > 27 kgf and women > 15 kgf. Low handgrip strength: men ≤ 27 kgf and women ≤ 15 kgf

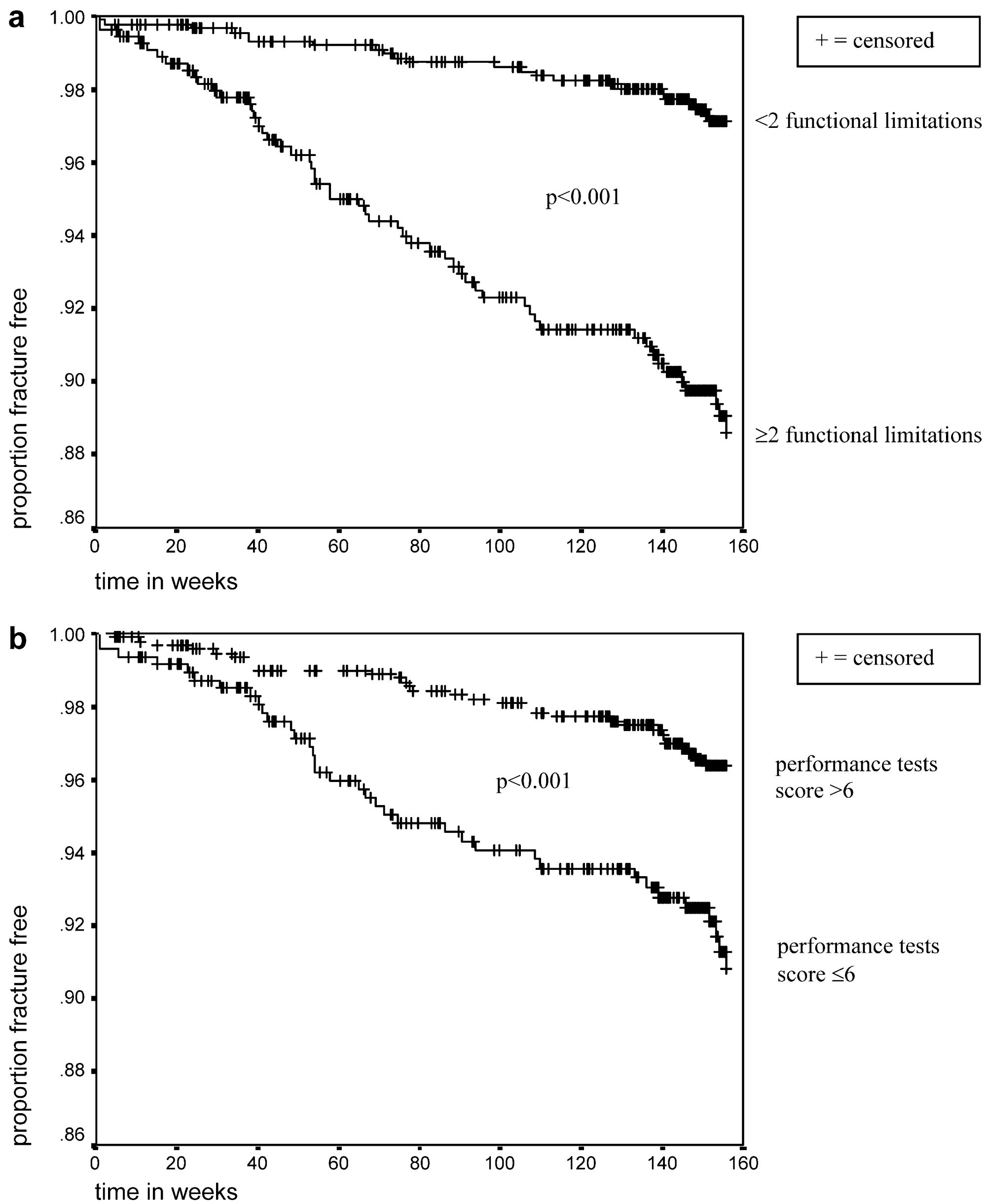


Fig. 1a–d The Kaplan-Meier survival curves of the associations between the risk factors and fractures: **a** functional limitations ($n = 1453$); **b** performance tests ($n = 1394$); **c** handgrip strength ($n = 1435$); **d** physical activity ($n = 1340$)

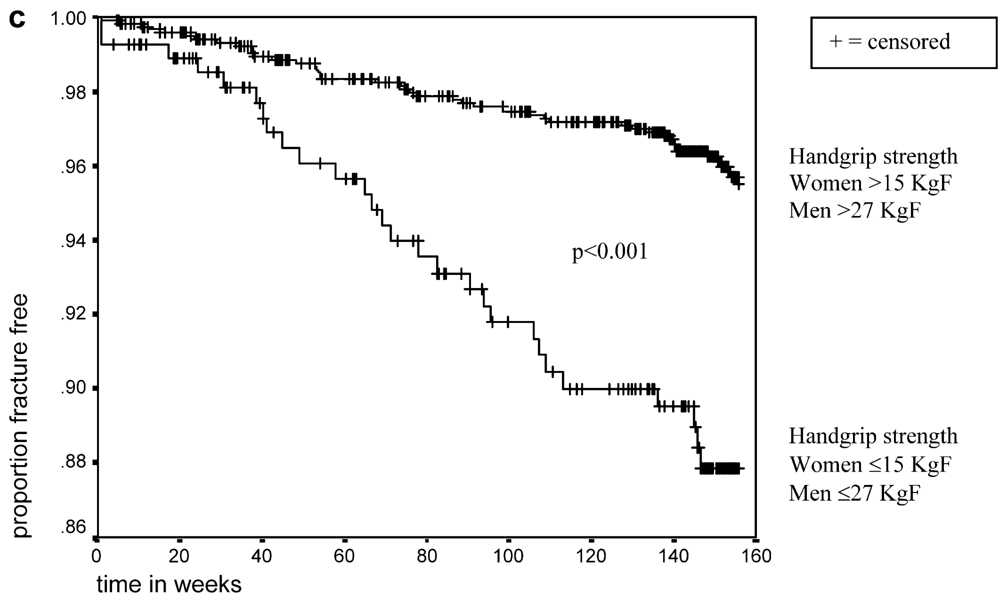
low handgrip strength were independent risk factors for fractures, whereas low physical activity was not (Table 4). No significant interaction terms were found for age and gender. Neither physical activity nor functional limitations or physical performance were significant effect modifiers.

Concerning each of the physical performance tests, the walking test was significantly associated with fractures, after adjustment for age and sex (RR = 2.1; 95% CI, 1.2 to 3.5), and after additional adjustment (i.e., physical activity) (RR = 2.0; 95% CI, 1.1 to 3.6), whereas the chair stands and tandem stand were not.

Cox proportional hazard regression was also performed with all risk factors simultaneously. Only functional limitations were significantly associated with fractures (RR = 3.0; 95%CI, 1.6 to 5.8), whereas performance tests (RR = 1.2; 95%CI, 0.7 to 2.3), handgrip strength (RR = 1.6; 95%CI, 0.9 to 3.0), and physical activity (RR = 1.2; 95%CI, 0.7 to 2.1) were not. Of the 1,477 respondents, 414 respondents (30.1%) had none of the risk factors, 469 respondents (31.8%) had one risk factor, 340 respondents (23.0%) had two risk factors, and 224 respondents (15.2%) had three risk factors, taking performance tests and handgrip strength as one risk factor (i.e., poor physical performance). After adjustment for age and sex, the risk of fractures for respondents with one risk factor was RR = 2.2; 95%CI, 1.0 to 5.0, with two risk factors RR = 5.2; 95%CI, 2.3 to 11.7, and with three risk factors RR = 4.4; 95%CI, 1.8 to 10.7, compared with respondents with no risk factors.

Similar to the results of the dichotomized risk factors, Cox proportional hazard regression with continuous risk factors shows that functional limitations (RR = 1.2;

Fig. 1a–d (Contd.)



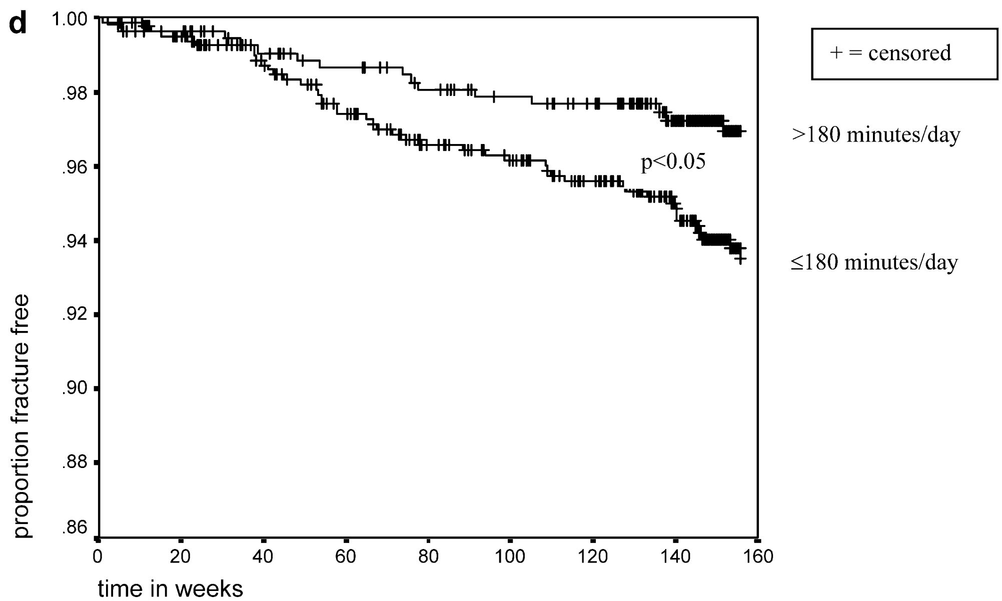


Table 4 Relative risks relating functional limitations, physical performance, handgrip strength, and physical activity, to fractures, unadjusted and adjusted for age and sex and other potential confounders (Cox proportional hazard model). Data are relative risks (95% confidence intervals)

	Functional limitations, ≥2 limitations	Physical performance		Physical activity (≤ 180 min/day)
		Performance tests, score ≤ 6	Handgrip strength (M ≤ 27 kgf, W ≤ 15 kgf)	
Unadjusted	4.2 (2.6–6.8)*	2.5 (1.6–4.1)*	3.0 (1.9–4.8)*	2.1 (1.2–3.8)*
Adjustment for confounders				
Age and sex	3.5 (2.1–6.0)*	1.9 (1.1–3.3)*	2.5 (1.5–4.1)*	1.9 (1.1–3.5)*
All potential confounders[a]	3.2 (1.8–5.5)*	1.8 (1.0–3.3)*	2.0 (1.1–3.6)*	1.5 (0.8–2.8)

*$p < 0.05$

[a]After adjustment for age and sex, additional adjustment was only made for those confounders that changed the β by at least 10%. Body mass index, number of chronic diseases, medication use, dizziness, fracture in past, cognitive impairment, depression, current smoking, and alcohol use did not change the associations by at least 10%. Functional limitations were additionally adjusted for handgrip strength and physical activity; performance tests were additionally adjusted for physical activity; handgrip strength was additionally adjusted for physical activity; and physical activity was additionally adjusted for functional limitations and performance tests

95%CI, 1.1 to 1.4 for an increase of one functional limitation), physical performance tests (RR = 1.1; 95%CI, 1.0 to 1.2 for a decrease of one point of the score), and handgrip strength (RR = 1.9; 95%CI, 1.3 to 2.9 for a decrease of 10 kgf) were significantly associated with fractures, whereas physical activity was not (RR = 1.1; 95%CI, 0.9 to 1.4 for a decrease of 1 h of activity) after adjustment for all potential confounders. Additionally, almost similar results were obtained using only definite fractures ($n = 70$ fractures), if we took the intensity of the physical activities into account (using MET scores) or used the number of physical activities (≤ 3 versus > 3 activities) (Table 4). Neither the most inactive persons (25th percentile: ≤ 65 min per day) nor the most active persons (75th percentile: ≥ 240 min) was significantly associated with fractures after adjustment for potential confounders. The weight-bearing activities and the individual activities were not independent risk factors for fractures, after adjustment for age and sex.

Discussion

This 3-year prospective population-based cohort study in older men and women extends the findings of previous studies by investigating the association between different aspects of functioning (i.e., functional limitations, physical performance, and physical activity) and fractures, within one study. Functional limitations and poor physical performance were independent risk factors for fractures.

In this study, men sustained more hip fractures than women. This finding might be partly due to the LASA sample, consisting of a relatively large number of older men, because the sample was stratified by age and sex. However, this remarkable finding might also be caused by coincidence, because the number of hip fractures is relatively small. Furthermore, the number of vertebral fractures might be underreported, because only one out of three vertebral fractures detected by radiograph comes to clinical attention or to the attention of the patient [20]. Additionally, the prevalence of vertebral deformities was determined in a substudy of LASA, using radiographs only (including symptomatic and nonsymptomatic fractures). The prevalence of having at least one vertebral deformity was 39% in both men and women aged 65 years and over [2].

Self-reported functional limitations seemed to be more strongly associated with fractures than the performance-based measures of functioning. An advantage of self-reported functional limitations is that the questions are based on activities of daily living and are easily measurable, and no equipment is needed. However, a disadvantage is that they are based on self-reports and may be influenced by cognition, culture, and education. Performance-based measurements minimize the difficulties associated with self-reports, but are performed in standard settings and therefore may not fully reflect activities performed in daily life.

The few studies that examined the association between self-reported functional limitations and fractures also found that self-reported functional limitations increased hip fracture risk in men and women [21] or in women only [5]. In line with our results, poor physical performance was associated with a higher fracture risk in other studies [8, 22]. In the present study, only the walking test was an independent risk factor for fractures, whereas the other performance tests (i.e., chair stands and tandem stand) were not. Walking reflects muscle strength, balance, and coordination and is the most common activity among older persons. In a previous LASA study, walking activity was associated with higher bone mineral density [23]. Moreover, another study also showed that walking can reduce fracture risk among postmenopausal women [24]. In contrast with our results, other investigators found that balance (tandem stand or postural sway) appeared to be an independent risk factor for fractures [8, 9]. These differences might exist because the balance tests in other studies were mainly performed in clinical centers, whereas the LASA study is performed at home. Another explanation for these differences might be that the LASA sample consisted of a relatively healthy older population. Most LASA respondents could complete the tandem stand for 10 s (ceiling effect). The predictive value of the tandem stand might be better if the tandem stand is assessed for more than 10 s [25]. In previous studies in the LASA cohort and in other studies, poor balance was a risk factor for falls [7, 26], which cause more than 90% of hip fractures [27]. In addition to balance, functional status and other measures of physical performance were also risk factors for falls [7, 28]. Moreover, functional status and physical performance can be improved by training [29], and these risk factors may therefore be valuable for intervention strategies. Future research, however, should examine more clearly to what extent functional limitations or physical performance are treatable in older persons. Additionally, in controlled clinical trials it should be tested whether improvement of these factors can indeed reduce the number of fractures.

In the present study, physical activity was associated with fracture risk, but this association was no longer significant after adjustment for confounders. It was suggested that the relationship between physical activity and fractures might be U-shaped, in which the most active and the most inactive persons might be at highest risk [24]. In the current study, however, neither the most active nor the most inactive persons had a significantly higher fracture risk. A review that assessed the relationship between physical activity and fractures among older adults found that physical activity may reduce the risk of hip fractures by 20–40% [30]. However, the few studies that examined the association between physical activity and the risk of other common osteoporotic fractures, such as vertebral and wrist fractures, did not find physical activity to be protective [30]. Therefore, the lack of association between physical activity and fractures in the current study might be partly explained by the inclusion of all fractures.

Physical activity (i.e., enacted aspect of functioning) measured with the LAPAQ provided information about the frequency and duration of functioning, but was based on self-reports. Objective measures of physical activity (i.e., doubly labeled water method, accelerometer, or pedometer), however, are not suitable for large epidemiologic studies in older people [16]. Moreover, these measures do not provide information about specific activities. In the current study, however, the individual and weight-bearing activities were not significantly associated with fractures.

High physical activity may increase fracture risk in respondents with functional limitations or a low physical performance [11]. However, we did not find that the association between functional limitations, physical performance, and fractures was different for respondents with a higher or lower levels of physical activity. Only one other study has examined the effect of physical activity on fractures among subgroups of community-dwelling older people [31]. In contrast with our results, the last-mentioned case-control study observed that physical activity was a significant effect modifier in the association between functional limitations and fractures. The contrasting results might be due to the differences in the number of fractures, which was higher in the last-mentioned case-control study ($n=471$) compared with our prospective study ($n=77$). Respondents with one risk factor had a twofold fracture risk, whereas respondents with two or three risk factors had a four to fivefold fracture risk. The results should be interpreted with caution, because of the small number of respondents and of fractures in the groups with two and three risk factors.

Several limitations of this study should be mentioned. First, although the study consisted of a large sample size, the number of fractures was limited. Therefore, inferences about associations and effect modifiers should be interpreted with caution. Because of the limited number of fractures we could not differentiate between the types of fractures. Second, the assessment of fractures was based on self-report. Although this method has been shown to be accurate [32], there may have been persons who had a fracture that they never reported. This may have led to an underestimation of the studied associations.

In conclusion, functional limitations and poor physical performance were independent risk factors for fractures. Moreover, the easily measurable functional limitations appear to be more strongly associated with fractures than physical performance. Functional status and physical performance can to some extent be improved, and may therefore suitable for intervention strategies for the prevention of fractures.

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